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(54) **Method and apparatus for separating gas with a pump from a medium being pumped.**

(57) The present invention relates to a method and apparatus for separating gas by a pump from the medium being pumped, which method and apparatus are especially suitable in pumping the gaseous fiber supensions in the wood processing industry. In known apparatus, it has been difficult to prevent solids from entering the gas discharge system fur guiding the gas out of the pump so that the system would clog and give rise to the necessity for expensive and time-consuming reparation.

The method and apparatus in accordance with the present invention eliminates or minimizes the above disadvantages in that rear vanes (11) of the pump or the members operating together with them are arranged in such a way that they either direct the flow of the medium, generated by the combined effect of forces with different directions and different intensities directed at the medium in the space behind the impeller in the vane gaps of said rear vanes, past a gas discharge opening (12) in the rear wall of the pump, or they dampen the flow so that its extension to said gas discharge opening (12) is prevented.

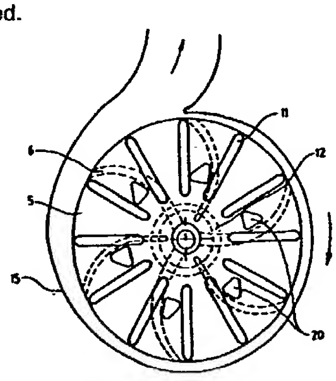

FIG. 3

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METHOD AND APPARATUS FOR SEPARATING GAS WITH A PUMP FROM A MEDIUM BEING PUMPED

The present invention relates to a method and apparatus for separating gas with a pump from a medium being pumped. More precisely, the apparatus in accordance with the invention relates to the gas discharge arrangement of a pump used in the pumping of a medium containing gas. The pump in accordance with the present invention is especially suitable for pumping low, medium and high consistency fiber suspensions of the pulp and paper industry.

It is already well known that pumping of liquid containing gases may not be carried out at higher gas contents without gas discharge, because gases accumulate around the center of the rotor of the pump and form a bubble which grows tending to fill the whole inlet opening of the pump. This results in a considerable decrease of efficiency and vibration of the equipment and in the worst case in the interruption of the pumping. This problem seems to be especially difficult, for example, in centrifugal pumps, which have been used for decades, for example, for pumping, low consistency fiber suspensions in the wood processing industry. Various attempt have been made to solve said problems by discharging gas from the bubble. Gas is nowadays discharged in known and used apparatuses either by drawing gas with suction through a pipe, which extends to the hub of the impeller located in the center of the suction opening of the pump,. by drawing it through a hollow shaft of the impeller or by arranging at least one hole in the impeller, through which hole/holes gas is drawn to the back side of the impeller and further away therefrom. All said apparatuses operate satisfactorily when the medium being pumped is liquid or the like and free from solids. Problems arise only when the medium includes solid particles, such as fibers, threads, etc. In such cases these particles risk the ducts remaining clear and open, which gain is a necessity for the operation of the pump.

Of course, there are several known solutions by means of which the disadvantage and risk factors caused by the impurities are tended to be eliminated or minimized. The simplest way is probably to arrange a sufficiently large duct for the gas discharge so that clogging is out of the question. Other alternatives used are, for example, different blade wheel arrangement at the back side of the impeller. Very often radial vanes are arranged on the back surface of the impeller, the purpose of which vanes is to pump the medium, which has flowed with the gas through the gas discharge openings of the impeller to the outer rim of the impeller and from its clearance back to the liquid flow. The ultimate purpose of the vanes behind the impeller is to balance the axial forces of the pump, which is considered to be carried out best, when the amount of the rear vanes is similar to that of the actual pumping vanes. In some cases a separate arrangement is used having the same purpose as the above mentioned, but which is mounted further behind the impeller by means of a blade wheel mounted on the shaft of the impeller. Said blade wheel rotates in its own chamber tending to separate the liquid flowing with the gas to the outer rim of the chamber the gas being thus able to be drawn by suction from the inner rim of the chamber. The medium with the impurities accumulated on the outer rim of the chamber is guided via a separate duct either to the suction or discharge side of the pump. All disclosed apparatuses operate satisfactorily only when a limited amount of impurities is included in the liquid. It is also possible to adjust said apparatuses to operate relatively reliably also with liquids containing plenty of solids, for example, fiber suspensions of the pulp industry. In that case it is, however, necessary to yield in the gas discharge ability, since the main purpose is to ensure that no or hardly any fibers drift to the gas discharge duct or to the vacuum pump possible communicating with it. Thus gaseous fiber suspension is, as a precaution, fed back to the flow. On the other hand, it is known that the gas in the fiber suspension is a negative factor in the pulp treatment process, which factor should be eliminated as well as possible. It is a waste of the existing advantages to feed the once-separated gas back to the pulp circulation. It is also a waste of pulp to separate all the pulp flowed with the gas from the pulp circulation by discharging it as a secondary flow of the pump.

The purpose of the present invention is thus to utilize most efficiently the capability of a centrifugal pump to separate gas from liquid, which gas is discharged from the pump itself by the simplest and operationally proof means. The only precondition is to be able to operate without a risk of the impurities flowing with the liquid, i.e. solids, such as threads, fibers, etc., being able to clog the gas discharge system.

The pending Finnish application 872967 (corresponding US appln. No. 216,009; ONLY FOR OUR US patent agent) discloses some methods by which it may be ensured that, even if the material to be pumped were fiber suspensions of the pulp and paper industry, the fibers of the suspension cannot clog the gas discharge system or the vacuum pump communicating with it. In said application a filter surface or the like is arranged in the flow passage of the gas being discharged prior to the

vacuum pump possibly used in the process, by which surface the fibers of the suspension are prevented from entering the gas discharge system.

On the other hand, also US patent publication 4,673,330 discloses a method of controlling the operation of a centrifugal pump in such a way that the pump is dimensioned to the desired lift height and capacity by adjusting the size of the gas bubble generating in front of the pump.

The arrangement in accordance with said publication comprises a plurality of electric sensors arranged radially on the housing of the pump behind the impeller on the rear wall, which sensors measure the size of the gas bubble generating between the impeller and said rear wall on the basis of the varying ability of liquid and gas to conduct electricity or the like ability.

It is noted in said publication that neither the medium between the vanes of the impeller nor the gas bubble inside the medium are evenly round, but the boundary surface between them is to some extent serrate in such a way that each foil in a way pushes the medium layer in front of it and the medium layer tends to move towards the outer rim due to the centrifugal force. However, for a reason not explained in the publication the portion of the medium which is on the surface of such pushing vane is closest to the center of the impeller. Such regularity prevails not only with the actual pumping foils, but also with the so called rear vanes radially arranged behind the impeller according to the publication.

According to our invention and due to the fact that the factors resulting in the wavy form of the boundary surface between gas and said pulp in the previously described publication has been succeeded to explain thoroughly, it has become possible to define the dimensions of the rear vanes of the impeller and their location, the size and location of the gas discharge openings piercing the impeller and the dimensions of the central opening of the rear wall behind the impeller of the pump and the mutual dimensions of the above described parts in such a way that the discharge of gas from the centrifugal pump is possible without the above mentioned screen plate arrangement or also the above described guiding means of the pump based on electric sensors, which means could be used, by all means, also merely for adjusting the size od the gas bubble.

The basic principles of the arrangement in accordance with the present invention are following:

- the smallest radial measurement of the part of the gas bubble generating in the centre of the pump, which part is on the back side of the impeller, has to be larger than the radius of the central opening in the rear wall of the pump, so as not to allow any movable solid particles flowing with the medium into the gas discharge system;
- the highest radial measurement of the part of the gas bubble on the back side has to be in all operating conditions smaller than the radius of the impeller, so as not to allow the gas to flow back to the medium being pumped;
- the distance of the perforations for the gas discharge from the axial line of the pump has to be longer than the radius of the opening in the rear wall, so as not to allow any solid particles possibly flowing with the gas directly to be discharged into the gas discharge system.

Additionally, due to the serrated form of the gas bubble mentioned above the radial dimension of the medium layer has to be taken into consideration. In the worst case the above described conditions cannot be fulfilled, because the medium resting against the surface of the pushing vane may extend to the level of the opening of the rear wall and, on the other hand, the outermost part of the gas bubble may at the same time extend to the rim of the impeller. Thus a situation is reached, in which the opening of the rear wall has to be as small as possible, the limit being the size of the diameter of the shaft. On the other hand, the diameter of the impeller has to make as large as possible, the dimensions of the rest of the pump set the limit for it to a certain easily determined limit value. Also considering the different operating conditions of the pump, the variety of rotational speeds being used in different conditions and the media having different gas contents, the point will be reached at which the distance of the ultimate radial measurements of the gas bubble should be diminished as much as possible.

In addition to that, although the publications of the prior art disclose a great number of arrangements for the location of the gas discharge openings in the rear plate of the impeller, no proper advice or arrangement has been found. CH patent 571655 gives an example of an arrangement in which perforations have been arranged adjacent to the rear surface of the vane at variable radial distances from the shaft of the pump, the diameter of perforations diminishing outwards from the shaft. In another position, in the so called first generation MC- pumps the gas discharge opening for the medium consistency pulp have been arranged as oblong openings (Fig.2), which are located between the vanes of the impeller and extending almost from one vane to another at a similar radial distance from the shaft of the impeller. Thus the positioning of the gas discharge openings has been till today more or less accidental without any theoretical or even profound experimental definition.

The present invention relates to the fact that the dimension and the position of the rear plate of the impeller and the rear vanes in it and the dimen-

sions of the rear wall of the pump have been optimized and that the form of the boundary surface between the gas trouble and the liquid ring surrounding the bubble has been levelled to such an extent that in practice no or hardly any medium being pumped enters with the gas the gas discharge system.

The apparatus in accordance with the presence invention is characterized in that the rear vanes of the pump or the members operating together with them have been arranged in such a way that they either direct the flow of the medium, generated by the combined effect of forces with different directions and different intensities directed at the medium in the space behind the impeller in the vane gaps of said rear vanes, past the gas discharge opening in the rear wall of the pump or they slow down said flow so that its extension to said gas discharge opening is prevented.

The method in accordance with the present invention is characterized in that by guiding the flow of the medium, generated by the combined effect of the radial forces, forces parallel with the rim and inertial forces directed at the medium in the space behind the impeller, past the gas discharge duct leading to the gas discharge system or by damping the flow of the medium generated by the combined effect of said forces, the discharge of the medium in said space to the gas discharge system is prevented.

The following list gives examples of the advantages of the centrifugal pump in accordance with the existing arrangements:

- more effective discharge of gas, because it is not necessary to return gaseous liquid to the main circulation;
- in the pumping of fiber suspensions there is no risk of clogging the gas discharge ducts or the pulp being wasted or drifted to the sewage;
- the construction of the unit being used in the pumping becomes simpler, the use becomes more reliable, and the running costs reduce, because a vacuum pump does not necessarily require a separate driving motor;
- it becomes possible to pump pulps with considerably higher consistencies, because the high content of air in high consistency pulps has with the prior art arrangements prevented the pumping.

The method and apparatus in accordance with the present invention may be applied to the conventional centrifugal pumps, whereby it is, of course, necessary to compromise with the consistency of the pulp being pumped, but also to MC-pumps in accordance with the prior art, whereby it is possible with these pumps provided with rotors extending to the suction opening to treat considerably thicker pulps than before.

The apparatus in accordance with the present invention and the method used with it are described below, by way of example, with reference to the accompanying drawings, in which:

Fig. 1 is a sectional side view of a centrifugal pump in accordance with the prior art technique and its gas discharge system;

Fig. 2 is a schematic back view of an impeller of a centrifugal pumpin accordance with the prior art;

Fig. 3 is a schematic back view of an impeller of a centrifugal pump in accordance with an embodiment of the present invention;

Fig. 4 is a schematic back view of an impeller of a centrifugal pumpin accordance with a second embodiment of the present invention;

Fig. 5 is a schematic back view of an impeller of the centrifugal pump in accordance with a third embodiment of the present invention;

Fig. 6 is a schematic view of arrangements in accordance with some other embodiments combined together in one drawing seen from the back side of the impeller; and

Figs. 7a and 7b visualizes the forces affecting each pulp particle behind the impeller.

The so called first generation centrifugal pump for medium consistency fiber suspensions (so called MC-pump) in accordance with Fig.1, which is described more in detail, for example, in US patent publication 4410337, mainly comprises in principle following elements: a housing 1 of the pump, a suction opening 2 therein, a discharge opening 3, a shaft 4 of the pump, an impeller 5 provided with pumping vanes 6 and mounted on the shaft, a rear plate 7 of the impeller, a rear wall 8 of the pump and a gas discharge conduit 9. Gas discharge openings 10 of impeller 5 described in the figure are located in close proximity to the shaft 4 of the pump, because thus one has tried to ensure that no or hardly any fibrous liquid is allowed to the gas discharge system. So called rear vanes 11 have been arranged radially to the back side of the rear plate 7 of the impeller, and they have two purposes in this type of a pump. On one hand, they equalize the axial forces in the pump and, on the other hand, they also tend to pump the liquid, which has flowed behind the rear plate, back to the main flow towards the pressure opening 3. Corresponding openings 10 of the impeller an annular duct 12 has been maintained around the shaft in the rear wall of the pump, through which duct the gas is discharged to the space 13 on the back side of the rear wall 8, from which space the gas discharge conduit 9 leads the gas further, most usually through a separate vacuum pump away from the pump.

Fig. 2 illustrates a back view of the impeller 5 used in reality in the arrangement in accordance

with said US patent. As can be seen, the number of the so called rear vanes 11 on the back side of the impeller is six, which amount has become established. Also, generally the aim has been to minimize the amount of the rear vanes, but in the end the number has been settled to six, because also the number of the actual pumping vanes on the opposite side of the impeller in the arrangement is in practice six. Furthermore, said rear vanes 11 have always been in the prior art arrangements radial so as to simplify the manufacture and because no reason for their directing otherwise has come about. The figure also illustrates the construction and the location of the gas discharge openings 10. in other words, the openings are oblong the curved parallel to the rim of the impeller being therefore constantly at the equal distance from the shaft of the pump. The figure also illustrates the annular duct 12 remaining between the rear wall of the pump and the shaft of the impeller, through which duct gas flows into the gas discharge system.

Additionally, a arrow A shows in Fig.2 the rotational direction of the impeller and the boundary surface between an air bubble on the back side of the impeller and the fiber suspension surrounding it and sketched by a broken line 14, which boundary surface forms the serrate figure described already in connection with the prior art technique. It should be noted that the form of the gas discharge openings with the constant radial distance is not the best possible, because a corresponding serrate figure is formed also on the opposite, the actual pumping side of the impeller. Therefore, it may be stated that, although the part of the gas discharge opening, close to the back side of the pumping vane very efficiently allows the flow of the gas from the front side of the impeller to the back side, the opposite end of the gas discharge opening is in the fiber suspension zone, whereby some of the fiber suspension flows to the back side of the impeller, which alone is undesirable. On the other hand, it is noted that the radial measurement of the gas bubble is at its greatest very close to the outer edge of the impeller, so if gas is not efficiently enough drawn away from said space, there is a risk that the gas bubble begins to be discharge back to the main flow from the outer rim of the impeller. If such a situation were encountered in practice, compromises should be made in the gas discharge ability of the pump, because there is also the counterrisk that, if the suction effect of the vacuum pump drawing gas is increased, fiber suspension enters gas discharge system from the annular gap between the rear wall of the pump and the shaft, whereby the liquid ring pump operating most usually as the vacuum pump might clog almost immediately and might result in both service and possibly also reparation operations.

The main reasons for the formation of the described serrate figure are described below. When the pulp is discharged from the openings of the impeller to the back side of the impeller, said pulp has a rotational speed substantially corresponding the circumferential speed of said openings. The pulp is subjected on the back side of the opening to a centrifugal force, which tends to throw the pulp outwards, whereby the motional direction of the pulp due to the inertia tends to be, not radial, but curved backwards relative to the movement of the impeller. In other words, the pulp tends to maintain the same circumferential speed, which it had when being discharged from the opening regardless the fact that it constantly moves outwards in the rim, whereby the impeller tends to "pass" the pulp due to the continuously increasing difference in the circumferential speeds. Thereby, the pulp, when moving outwards, flows to the surface of the rear vane next to the opening, which rear vane accelerates the circumferential speed of the pulp. Because new pulp constantly accumulates along the surface of the rear vane outwards towards the rim of the impeller, the part of the pulp, the circumferential speed of which has become higher, must move forward parallel to the rim towards the rear surface of the preceding vane, whereby a more or less inclined boundary surface between pulp and gas is formed to each vane gap. In addition to said circumferential speed and centrifugal force, there is a force affecting the pulp between the vanes, which force is due to the pressure changes of the guiding apparatus of the pump, for example, a spiral, and which is varying in intensity and is directed towards the shaft of the pump. Said force, according to the description, tends to push the pulp towards the shaft of the pump and more precisely tends to press the pulp through the central opening in the rear wall of the pump to the gas discharge system. It is a known fact that when the guiding apparatus of the pump is a spiral the pressure is at its highest substantially at the discharge opening of the pump, from where onwards it considerably evenly diminishes when moving against the rotational direction of the impeller, and being at its lowest in the part of the guiding apparatus immediately following the discharge opening in the rotational direction.

Fig.3 illustrates a back view of an impeller arrangement 5 of the pump in accordance with an embodiment of the present invention and corresponding to Fig.2. First of all, it is noted in the figure that the number of rear vanes 11 has been increased. The reason for that is that by operating this way it is possible to make the serrate form of the boundary surface between the gas bubble and the fiber suspension considerably more even. In a

way the peaks in both direction have been cut off. An explanation for this lies in that, because there are several rear vanes 11, the centrifugal force together with the inertial force may not spread the boundary surface between the fiber suspension and the gas bubble radially to a very large area. When the radial forces caused by the presence changes of the guiding apparatus 15 and their effects are also taken into consideration in this embodiment, it can be maintained that by increasing the number of the rear vanes 11 the sectors become narrower and the effect time of a pressure peak on the pulp in one separate sector diminishes and the number of sectors being sufficient an intensive pressure stroke has not time to accelerate the kinetic speed of the pulp towards the shaft high enough that the pulp would manage to flow to the gas discharge opening 12 in the rear wall 8 of the pump, but when the impeller 5 winds forwards said sector reaches the low pressure zone, whereby the centrifugal force tends to move pulp back towards the outer rim of the impeller.

Thus this change ensures that gas does not easily flow back to the main flow of the suspension, although a considerably modest underpressure might be used in the gas discharge system. On the other hand, the use of a considerably high underpressure either cannot generate the flow of liquid from the front side of the impeller of the pump through the gas discharge openings to the back side of the impeller or, correspondingly, from the back side of the impeller, to the gas discharge system. It is, of course, possible in practice to use also so high underpressure that fibers enter the gas discharge system, but this would require a considerably overdimensioned underpressure with the apparatus in accordance with the present invention. The real advantage of the invention is that a pump provided with an impeller in accordance with the present invention operates more reliably in changing operating conditions, because the boundary surface between the gas bubble and the liquid ring is at each point farther from both the outer edge of the impeller and the gas discharge opening or the central opening in the rear wall of the pump. Thus the present invention has brought about a considerable margin for the different risk factors.

Furthermore, the operation of the gas discharge system of the pump may be facilitated by locating the gas discharge openings 20 in impeller 5 at exactly right positions. Most advantageously gas discharge opening 20, of course, has to be located to each vane gap of the pumping side of impeller 5 or to each space between the lines drawn from the inner edge of each pumping vane 6 (shown with broken lines) to the axial line of impeller 5. It was already noted above that the ablong gas discharge opening (10; Fig.2) of the MC-pump in accordance with the prior art does not have a very advantageous form for the reason already mentioned above and is not advantageously located, either. Openings 20 are most optimally located and formed when the form of the edge on the side of the boundary surface between the gas bubble and the liquid ring follows the form of the boundary surface (14; Fig.2) and is nevertheless located as far from said boundary surface as possible. This results in the gas discharge openings 20 shown in Fig.3, which are substantially triangle and are located in this case to the suction side of every other rear vane 11, in other words relative to the rotational direction to the back side of vane 11. The figure illustrates two rear vanes 11 for each pumping vane 6 of impeller 5 and yet in such a way that every other rear vane 11 is located at least partly at the pumping vane 6. If the gas discharge openings 20 have the form shown in the figure and are located at the position shown in the figure it is possible to change the position of the gas discharge openings 20 slightly further out on the impeller 5 so as to gain more safety margin between the radial distances of the central opening 12 of the rear wall 8 of the pump and the gas discharge opening 20. Yet, it must be born in mind that the described triangle form is only a preferred embodiment and it is, of course, possible that the openings are, for example, round perforations or that the openings are formed by several possibly round perforations.

An embodiment worth mentioning is the inclination of the rear vanes 21 to slightly more pumping, shown in Fig.4, in other words vanes 21 are inclined in a way backwards around the point at the end closest to the shaft, whereby the material being pumped is subjected to a motional component parallel to the rim and in addition to that also to a component intensifying the effect of the radial centrifugal force directed outwards by which component it is possible to move the boundary surface between the gas bubble and the liquid ring located on the surface of rear vane 21 of impeller 5 further on, whereby the form of the boundary surface becomes even more even. Additionally, the inclination of the vanes effects the increase in the length of the distance, which the pulp should flow during the effect time of a force component caused by a pressure peak of the volute 15 and directed towards the shaft in order to manage to reach the gas discharge duct 12 of the rear wall of the pump. This further ensures the fact that the pulp has no time to reach the gas discharge opening 12 before the pressure in the volute 15 decreases rapidly to its minimum, whereby the centrifugal force rapidly becomes superior to the movement towards the shaft caused by the inertia of the pulp and begins

to move the pulp back towards the volute. By using inclined rear vanes 21 it is possible to decrease the number of rear vanes compared with the previous embodiment, because the same reliability is gained with a smaller number of vanes. On the other hand, it is also possible to incline the rear vanes forwards to some extent, whereby a corresponding combined effect of forces, in other words the effect decelerating the flows of the pulp is gained.

. The performed experiments prove right the basic idea of the above described theory that by inclining the vanes it is possible to decrease their number and also that the increase of the rotational speed of the impeller also decreases the number of the vanes required. The vane frequence required with straight radial vanes has been determined in experiments to about 370 Hz (number of vanes * rotational speed of the impeller r/s), so as not to let the pulp flow to the gas discharge system. By inclining the vanes it is possible to count the number of vanes by the following formula:

$z * n / \sin\beta > 370,$

in which $\underline{z}$ is the number of vanes as an integer,
$\underline{n}$ is the rotational speed of the impeller in r/s, and
$\underline{\beta}$ is the angle between the average direction of the rear vane and the tangent of the rim of the impeller. Thus the number of vanes gained is $z > 370 * \sin\beta/n$,
so, for example, when the angle β is 45° and the rotational speed n about 50 r/s, this results in that the required number of vanes is at least 6, whereas with straight vanes the angle B being 90° the formula results in 8 as the number of vanes.

Yet another embodiment is illustrated in Fig.5, which has two rear vanes 31 and 32 for each front vane 6. According to the figure the rear vanes are all inclined backwards as already in the previous figure, additionally the rear vanes the curved and vane 31 following gas discharge opening 20 in the rotational direction is of full length extending from the outer edge of gas discharge opening 12 in the rear wall of the pump to the outer edge of impeller 5, whereas vane 32 preceding in the rotational direction the gas discharge opening 20 in the impeller 5 substantially extends from the rim formed by the edges of said gas discharge openings 20 closest to the shaft to the outer edges of impeller 6. Naturally, it is possible that the dimensions of said vanes 31, 32 deviate even to a considerable extent from the dimensions of the above described preferred embodiment yet not deviating from the inventive concept and the operational pattern being described below.

Fig. 5 visualizes how the pulp accumulated in the vane gaps 33-38 from gas discharge openings 20 of the impeller behaves firstly at different points of guiding apparatus 15 and additionally in vane gaps 33-38; 39-44, which are in principle of two types. The pulp in vane gaps 33-36 on the front side of the fully long vane 31 acts as already roughly described above. In other words, almost in all vane gaps 33-38 the boundary surface between the pulp and the gas forms a serrate figure in such a way that the pulp against the front surface of the fully long vane 31 is closer to the shaft than the part of the pulp which is against the rear surface of the preceding shorter vane 32. However, in foil gaps 37 and 38, namely in those gaps, which are affected by the highest pressure of guiding apparatus 15, which pressure has made the pulp flow towards the shaft, in those gaps the form of the boundary surface between the pulp and the gas is first turning (foil gap 37) and then has already turned to the opposite direction (vane gap 38). This is explained by the fact that the pulp in vane gap 37 has reached a certain circumferential speed, which it due to its slowness tends to maintain regardless the fact that when the vane gap is wound in the zone of higher pressure this causes the pulp moving towards the center, whereby the circumferential speed of the impeller 5 relative to the speed of the pulp parallel to the rim decreases and the pulp accumulates against the rear surface of the shorter vane 32 operating as the front edge of vane gap 38. Thus said boundary surface extends in vane gap 38 of Fig.5 already over gas discharge opening 20 of impeller 5 and gradually said boundary surface extends to the inner edge of the shorter vane 32, from where the flow still due to its inertia is discharged to the preceding vane gap 44, in which the centrifugal force throws the pulp towards the outer rim. A lower pressure of guiding apparatus 15 prevails also in the preceding vane gap 44, because it has already moved past the high pressure zone. At this stage the form of the boundary surface between the pulp and the gas must also be noted in vane gaps 39-44, in other words in those vane gaps which have no gas discharge opening 20 of impeller 5. Said form remains substantially parallel to the rim of impeller 5 all the time, because the changes of the circumferential speed of the pulp in said gaps 39-44 are minor and also the radial shifts of the pulp in said vane gaps are relatively small.

Other possible embodiment are arrangements shown in Fig.6, used either together or, especially, separately. First alternatives for eliminating the pressure effects of guiding apparatus 15 that come into question are, of course, both sealing of the outer edge of impeller 5, for example, by arranging the clearance between impeller 5 and the housing of the pump by a closing element so small in such a way that the pressure of guiding apparatus 15 would no affect disadvantageously to the back side of impeller 5, when the pressure is otherwise at its highest, and arranging the clearance between the

rear wall of the pump and the shaft by a corresponding closing element 51 respectively so small that the radial flow of the pulp decelerates in the vane gap at the pressure peak when the vanes are, for example, as in Fig.3.

Furthermore, it might be possible to design the rear vanes of impeller 5 in such a way that due to said pressure the movement of the radially inwards moving pulp is prevented, for example, by winding the inner end of the shorter vanes 52 to follow the form of the edge of opening 20 of impeller 5, whereby the pulp flowing along the rear surface of said vane 52 towards the center is forced to be discharged through said opening 20 to the front side of impeller 5 when the gas is correspondingly discharged through the clearance between the shorter and the longer vane towards the gas discharge opening 12 in the rear wall of the pump. It is, of course, not necessary that in the last mentioned embodiment the vanes were of different length or that there were two vanes for each pumping vane 6, whereby the inner edge of each rear vane is wound in the described way. Further, it is possible to arrange rear vanes, which in this case were equally long, slightly shorter than what is described above in such a way that when the fiber suspension moves towards gas discharge opening 12 it may flow to the preceding vane gap without a risk of the pulp escaping through the gas discharge opening in the rear wall of the pump to the gas discharge system.

Fig. 6 illustrates also a few other alternatives for the gas discharge openings of the impeller. It is, of course, possible that the openings are either separate round perforations 54 or a group of perforations 55 or even a great number of perforations, whereby in a way a filter surface is formed in the gas discharge opening.

Further, it is possible to arrange a discharge opening 56, for example, to each vane of the impeller moving in the rotational direction in front of a vane gap with an opening, from which discharge opening the pulp flowing due to the pressure of the guiding apparatus towards the shaft may be discharged to the preceding vane gap. Said discharge opening may be perforation 56, or a slot in the vane, a bevel in the area of one end of the vane, it may be an opening between the vane and the rear plate of the impeller or it may also be an actual break in the vane. One possibility, which, of course, comes into consideration is to arrange a discharge cut-out or even a flow duct in the rear wall of the pump in the area of rear vanes and further to the area in which the higher pressure of the guiding apparatus may influence the vane gaps, in other words between the center of the pump and the discharge opening. In all described arrangements the pressure of the guiding apparatus may be discharged to the vane gap/gaps next to it or even to some other vane gap (although the duct in the rear wall of the pump), which vane gap is in the area of the lower, or if the whole pressure field of the guiding apparatus is considered, the lowest pressure. It is, of course, possible to arrange a corresponding flow passage 57 into communication with the other vane 53, in other words the one being further behind in the rotational direction, which vane also limits the vane cap, whereby the pressure would be discharged in a corresponding way to the vane gap next to it, but the operational concept of this is not as elegant as the above described solution.

In addition to that a few other alternative arrangements may be mentioned, which are not shown in the drawings. Firstly, as mentioned already above, the clearance between the impeller and the housing of the pump may be arranged small in the area of the rear vanes in such a way that the curved plate shown in Fig. 6 is extended to cover the whole length of thr rim, whereby the rear vanes of the impeller rotate inside their own ring, in which ring openings have been arranged for the discharge of the material accumulated in the vane gaps to the guiding apparatus of the pump. When said perforations are positioned mainly in the area of the lower pressure of the guiding apparatus, the pressure of the guiding apparatus is not able to affect the pulp in the vane gaps.

It may also be considered that the effect of the pressure of the guiding apparatus may be diminished by decreasing the time, which the force component caused by the pressure of the guiding apparatus towards the center uses to accelerate the pulp in the vane gaps or by increasing the distance the medium must flow to reach the gas discharge duct. The first attempt to this is, or course, the above mentioned increase of the number of the vanes, but there are also other methods. Firstly, it is possible, for example, to bend strongly the outer ends of the vanes or the outer end of at least one of the vanes limiting each vane gap provided with a gas discharge opening of the impeller towards the other said vane limiting said vane gap in such a way that the dimension of the part of said vane gap open in the outer rim, which dimension is parallel to the rim, diminishes, whereby the effective time of the above mentioned force component naturally diminishes. Bending of the vane/vanes may be arranged, for example, in such a way that the top part of the vane is extended parallel to the rim towards another vane or that the vane as a whole is bent more towards another vane. Thereby the component towards the shaft caused by the pressure of the guiding apparatus creates a radial force directly affecting to the impeller. It is, or course, also possible that the vanes

are arranged, for example, in such a way that every other one is radial and the rest are bent backwards, whereby the vane gap either remains equally broad in the direction of the rim or it may even become narrower outwards. Further, it is possible to arrange one or more local constriction points between the rear vanes or to arrange the form of the rear vanes wavy in such a way that the distance which the flow runs from the outer rim of the impeller to the gas discharge duct becomes longer, whereby also the decelerating effect of the frictional forces on the movement of the pulp increases.

Figs. 7 a and b yet visualize the forces affecting each pulp particle which has flowed to the back side of the impeller through the gas discharge openings of the impeller. Fig. 7 a illustrates a situation, in which the pulp particle has just flowed through said opening to the back side of the impeller, in other words, a situation, in which the centrifugal force mainly determines the motional direction of the pulp particle, which is thus towards the rim of the impeller. Fig. 7 b illustrates a situation, in which the pulp particle is subjected to a so intensive radial force from the direction of the rim that also the particle moves towards the center of the impeller. In the figures different forces are referred to in the following way:
Fc = centrifugal force, Fi = inertial force, Fsp = radial force, which is due to the pressure of the guiding apparatus, Fb = force directed to the pulp particle from the rear vane. Additionally, the subindexes r and c refer to the radial component and the component parallel to the rim. Furthermore, the direction of the resultant R of said forces has been roughly sketched to the drawings and the resultant may be in reality deviate even considerably in size and in direction from the above described.

According to Fig. 7a, a centrifugal pump, to which the arrangement in accordance with the present invention may be applied, the pulp particle is subjected to a centrifugal force directed away from the shaft and to a force, which is due to the pressure of the volute of the pump directed towards the shaft, but which force is, however, less intensive than the centrifugal force. In addition to that, the particle is affected by an inertial force, has in the figure the shown direction, in other words decelerating the movement of the pulp particle relative to the impeller.

Furthermore, the pulp particle is subjected to a force component, both radial and one parallel to the rim, by the rear vane of the impeller in this case the rear vane being inclined, whereby the resultant R of the forces directed to the pulp particle has the direction of the tangent of the vane of the impeller.

In Fig. 7b the pulp particle is subjected to a powerful force towards the shaft, which is due to the pressure of the volute, in such a way that it even becomes superior to the centrifugal force. Thereby the inertial force tends to carry the pulp particle faster than the impeller in the direction following the rim, which effect is resisted by the rear surface of the rear vane in such a way that the direction of the resultant of all forces is parallel to the tangent of the rear vane. This figure especially clearly indicates the fact, when happens, when the force directed to the pulp particle of the rear vane ceases. In this case the force effect directed towards the shaft diminishes and the force effect parallel to the rim increases, whereby the direction of the pulp particle changes approaching the direction of the tangent of the rim. In other words, if the effect of the rear vane ceases prior to the central gas discharge opening of the rear wall of the pump, the direction of the pulp particle changes around the end of the vane, whereby the pulp particle is forced to the previous vane gap, in which on one hand the pressure effect of the volute is at its weakest and on the other hand the effect in accordance with Fig. 7a is at its highest.

As it is noted in the above description, a great number of arrangements has been developed, by which it is possible reliably to prevent the fiber suspension from flowing to the gas discharge system and in the vacuum pump in it. In the earlier arrangements it has been necessary for the above mentioned reason to arrange the vacuum pump to be run by a separate actuator, an apparatus outside the pump. However, now the present invention has brought about the possibility to use a vacuum pump in connection with the pumps used for pumping fiber suspension, an example being a so called liquid ring pump, to be used directly with the pump by the same actuator. In other words, a vacuum pump may be arranged to the same shaft inside the housing of the centrifugal pump without a risk of clogging the vacuum pump and of troublesome reparations.

Finally, it should be born in mind that the above description only illustrates a number of embodiments of a pump arrangement in accordance with the present invention, the scope of invention of which pump arrangement is not restricted to the above described most advantageous constructional solutions, by means of which it is merely shown how may different arrangement alternatives there are for realizing the method in accordance with the invention. Thus the scope of invention is restricted only be what is given in the accompanying claims. Thus, it must be noted that all those arrangements, in which the increase of the acceleration towards the center of the pulp or more exactly the gas discharge opening in the rear wall of the pump effected by the force components directed to the center of the pump by the pressure changes of the

guiding apparatus of the pump to such a level is prevented, at which level pulp is discharged to the gas discharged system, are included in the present invention. Additionally, it should be noted that the method and apparatus in accordance with the present invention may be applied to all pumps and respective apparatuses in which gas is discharged during the treatment.

Claims

1. A method of separating gas with a pump from a medium being pumped, in which method gas is separated from the medium being pumped to the center of a centrifugal pump on the front side of the impeller, from where gas is discharged through the impeller via the gas discharge openings in the impeller to the back side of the impeller, where the medium possibly flowed with the gas is discharged by means of rear vanes of the impeller from the gas, **characterized** in that by guiding the flow of the medium, generated by the combined effect of the radial forces, forces parallel with the rim and inertial forces directed at the medium in the space behind the impeller, past the gas discharged duct leading to the gas discharged system or by damping the flow of the medium generated by the combined effect of said forces, the discharge of the medium in said space to the gas discharge system is prevented.

2. A method in accordance with claim 1, **characterized** in that the flow, generated by the combined effect the centrifugal forces, forces parallel to the rim, inertial forces and the pressure changes of the guiding apparatus of the pump directed to the medium in the space on the back side of the impeller, which combined effect comprises a radial force component and a force component parallel to the rim, is guided or damped in such a way that the discharge of the medium in said space to the gas discharge system is prevented.

3. A method in accordance with claim 1, **characterized** in that the flow directed, due to the combined effect of said forces, along the rear surface of the rear vane of the impeller towards the shaft is allowed to be discharged with the guidance of the force component parallel to the rim to the van gap preceding in the rotational direction of the impeller.

4. A method in accordance with claim 2, **characterized** in that the combined effect of said forces is directed in such a way that the flow of the medium generated by said effect is guided past the opening leading to the gas discharge system, whereby the entrance of the medium to the gas discharge system is prevented.

5. A method in accordance with Claim 1, **characterized** in that the flow of the medium towards the shaft caused by the combined effect of said forces is guided towards the gas discharged opening in the impeller, from which opening the flow is allowed to be discharged to the front side of the impeller.

6. A method in accordance with claim 2, **characterized** in that the entrance of the pressure of the guiding apparatus is prevented to the space on the back side of the impeller, when the pressure of the guiding apparatus is adjacent to its maximum, by throttling said flow passage at the corresponding point.

7. A method in accordance with claim 2, **characterized** in tht the entrance of the flow of the medium towards the shaft, generated by the pressure peak of the volute, to the gas discharge system is prevented by throttling the flow passage leading to said system at the pressure peak of the volute.

8. A method in accordance with claim 2, **characterized** in that the pressure peak of the volute from accelerating the pulp in said vane gap towards the gas discharge opening leading to the gas discharge system by allowing the discharge of said pressure around the edge of the rear vane of the impeller or via the opening, slot or the like in the rear vane to the vane gap/gaps next to it.

9. An apparatus for separating gas from the medium being pumped by a pump, which comprises a housing (1) with suction and discharge openings (2,3), an impeller (5) arranged inside the housing and provided with pumping vanes (6), rear vanes and gas discharge openings, a rear wall (8) of the pump and means for the discharge of the gas from the pump, **characterized** in that rear vanes (11; 12; 31, 32; 52, 53) or the members operating together with them have been arranged in such a way that they either direct the flow of the medium, generated by the combined effect of forces with different intensities directed at the medium in the space behind the impeller in the vane gaps of said rear vanes, pas gas discharge opening (12) in the rear wall of the pump or they slow down said flow so that its extension to said gas discharge opening (12) is prevented.

10. An apparatus in accordance with claim 9, **characterized** in that rear vanes (11; 21; 31, 32; 52, 53) or the members operating with them have been arranged in such a way that they either direct the flow of the pulp in the vane gaps of said rear vanes being substantially towards the shaft of impeller (5) and mainly caused by the pressure differences of guiding apparatus (15) of the pump past the gas discharge opening (12) in the rear wall of the pump or they damp said flow, in other words

the effect of the pressure of the volute of tfe pump in such a way that its extension to the gas discharge opening (12) is prevented.

11. An apparatus in accordance with claim 9, **characterized** in that the number z of rear vanes (11; 21; 31, 32; 52, 53) of impeller (5) follows the formula
$z > 370 \cdot \sin\beta / n$, in which β is the angle between the tangent of the impeller and the average direction of the rear vane, and n is the rotational speed of the impeller r/s.

12. An apparatus in accordance with claim 9, **characterized** in that the there are more rear vanes (11; 31, 32; 52, 53) than there are pumping vanes (6) on the front side of impeller (5).

13. An apparatus in accordance with claim 12, **characterized** in that there are more rear vanes (11; 31, 32; 52, 53) is at least double the number of actual pumping vanes (6), whereby gas discharge openings (20) of impeller (5) are located, when seen from the back side of the impeller, maximally in every other vane gap depending, of course, on the relation of the number of the rear vanes and pumping vanes (6).

14. An apparatus in accordance with claim 9, **characterized** in that rear vanes (21; 31, 32; 52, 53) are inclined forwards or backwards.

15. An apparatus in accordance with claim 14, **characterized** in that said rear vanes (21; 31, 32; 52, 53) are inclined from the outer edge substantially backwards relative to the rotational direction of impeller (5) in such a way that the imaginary extension of said rear vanes being the tangent to the central gas discharge opening (12) in the rear wall of the pump.

16. An apparatus in accordance with claim 12, **characterized** in that vane (32; 52) preceding gas discharge opening (20) of impeller (5) in the rotational direction of the impeller is shorter than vane (31; 53) following said opening.

17. An apparatus in accordance with claim 9, **characterized** in that a flow passage has been arranged in the rear vane of impeller (5) from one vane gap to another.

18. An apparatus in accordance with claim 17, **characterized** in that said flow passage is a perforation (56), a gap, a bevel, or a slot (57) in said vane or a flow passage arranged at the rear vanes substantially between the center of the pump and the discharge opening; a cut-out or a duct leading to the area of lower pressure.

19. An apparatus in accordance with claim 9, **characterized** in that the inner end of vane (52) preceding gas discharge openings (20) of impeller (5) in the rotational direction of the impeller is arranged to follow in form the front and inner edge of gas discharge opening (20), in other words hook-like.

20. An apparatus in accordance with claim 9, **characterized** in that the flow surface area parallel to the rim of the vane gap in gas discharge opening (20) of impeller (5) has been deviated at some point from the conventional form substantially reminding a sector or a bent sector in such a way that it is either uniform through the whole radial length, radially outwards narrowing, throttled by arranging an extension parallel to the rim of the impeller at the end of at least one of the rear vanes, by arranging the rear vanes to be inclined to different directions or by arranging at least one local throttling point in said vane gap.

21. An apparatus in accordance with claim 9, **characterized** in that a closing element (50; 51) has been arranged at least between the pressure opening (3) of guiding apparatus (15) of the pump and gas discharge opening (12) in the rear wall of the pump, by which element fiber suspension is prevented from flowing to the gas discharge system.

22. An apparatus in accordance with claim 21, **characterized** in that a closing element (50) is mounted in the housing of the pump outside rear vanes (11; 21; 31, 32; 52, 53) of impeller (5).

23. An apparatus in accordance with claim 21, **characterized** in that a closing element (50) surrounds completely the rear vanes of impeller (5), whereby openings are arranged in said closing element (50) for the discharge of fiber suspension to the guiding apparatus (15) of the pump.

24. An apparatus in accordance with claim 21, **characterized** in that closing element (51) comprises a protrusion parallel to discharge opening (3) of the volute (15) of the pump at the edge of the central gas discharge opening (12) in the rear wall of the pump, which protrusion closes at that point gas discharge opening (12) otherwise surrounding the shaft of impeller (5), in other words it throttles the clearance between the rear wal and the shaft.

25. An apparatus in accordance with claim 9, **characterized** in that a vacuum pump has been arranged in communication with the pump in the gas discharge system.

26. An apparatus in accordance with claim 25, **characterized** in that a vacuum pump has been arranged on the same shaft with the impeller of the centrifugal pump or it is arranged to be run by a separate motor.

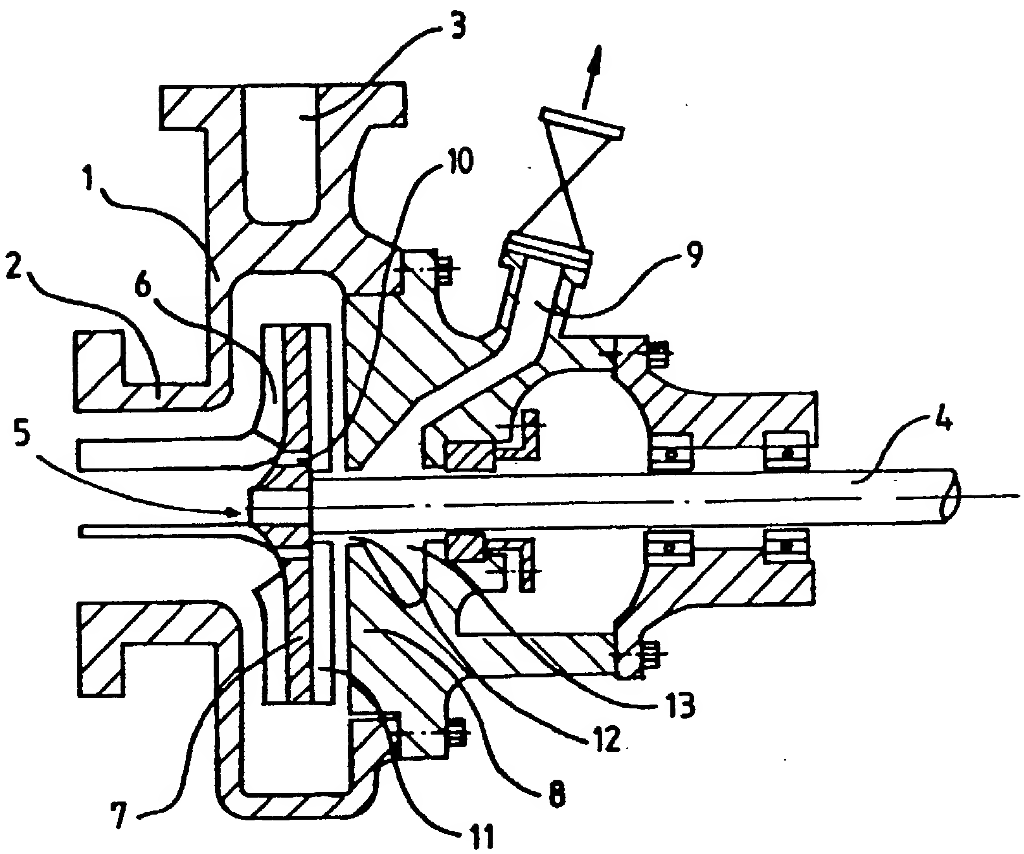

FIG. 1

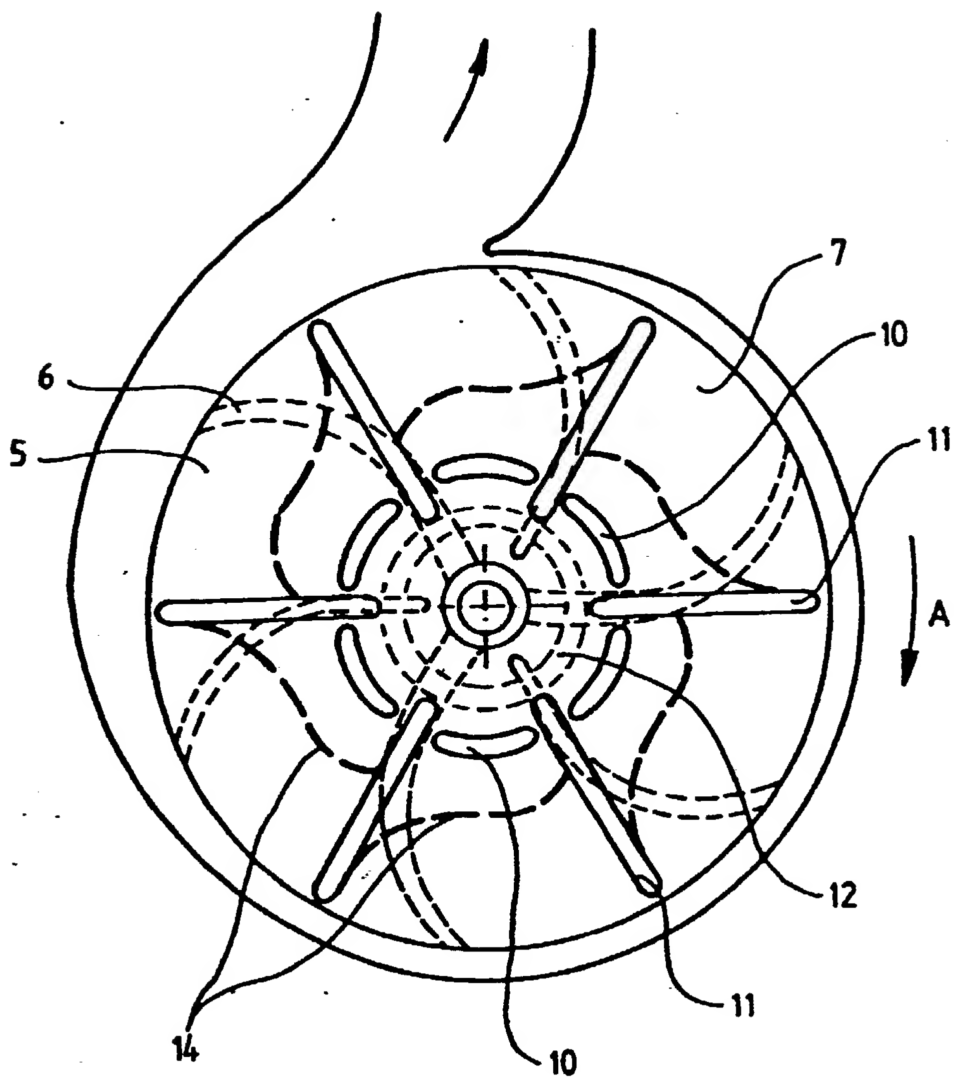

FIG. 2

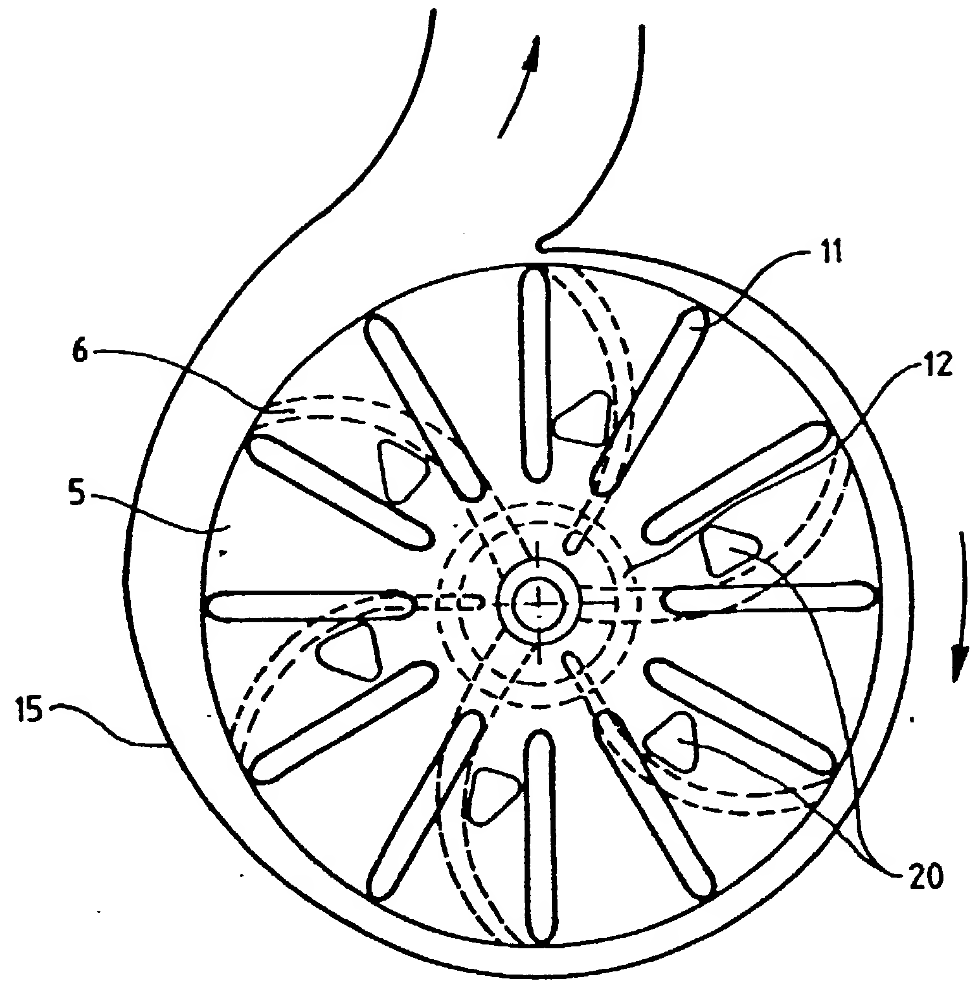

FIG. 3

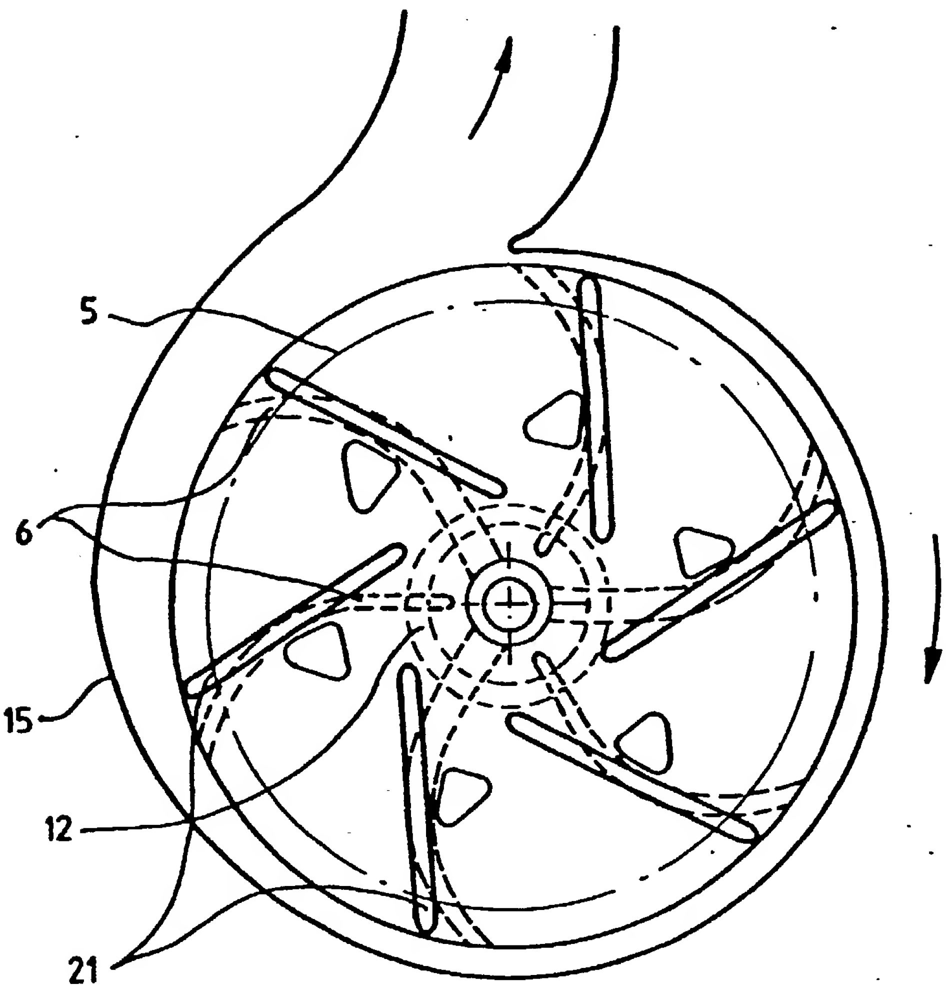

FIG. 4

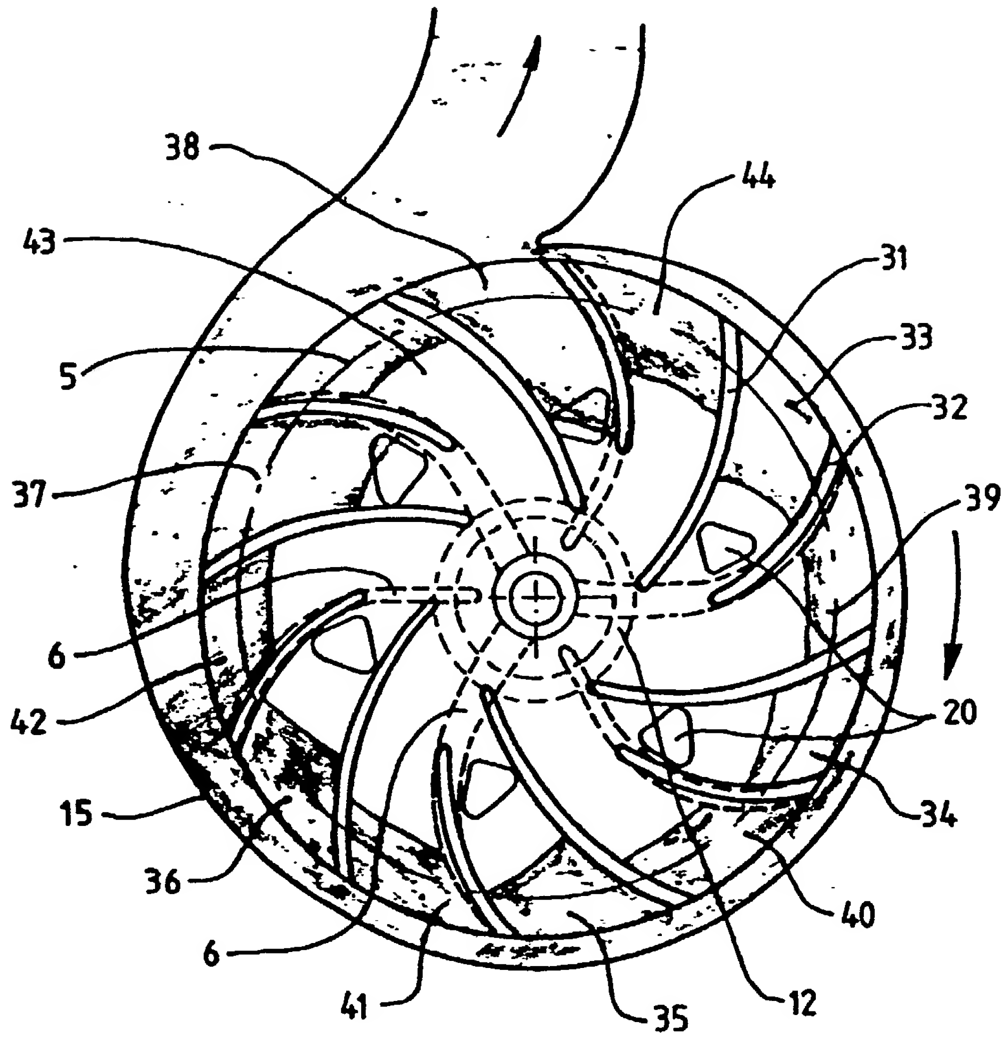

FIG. 5

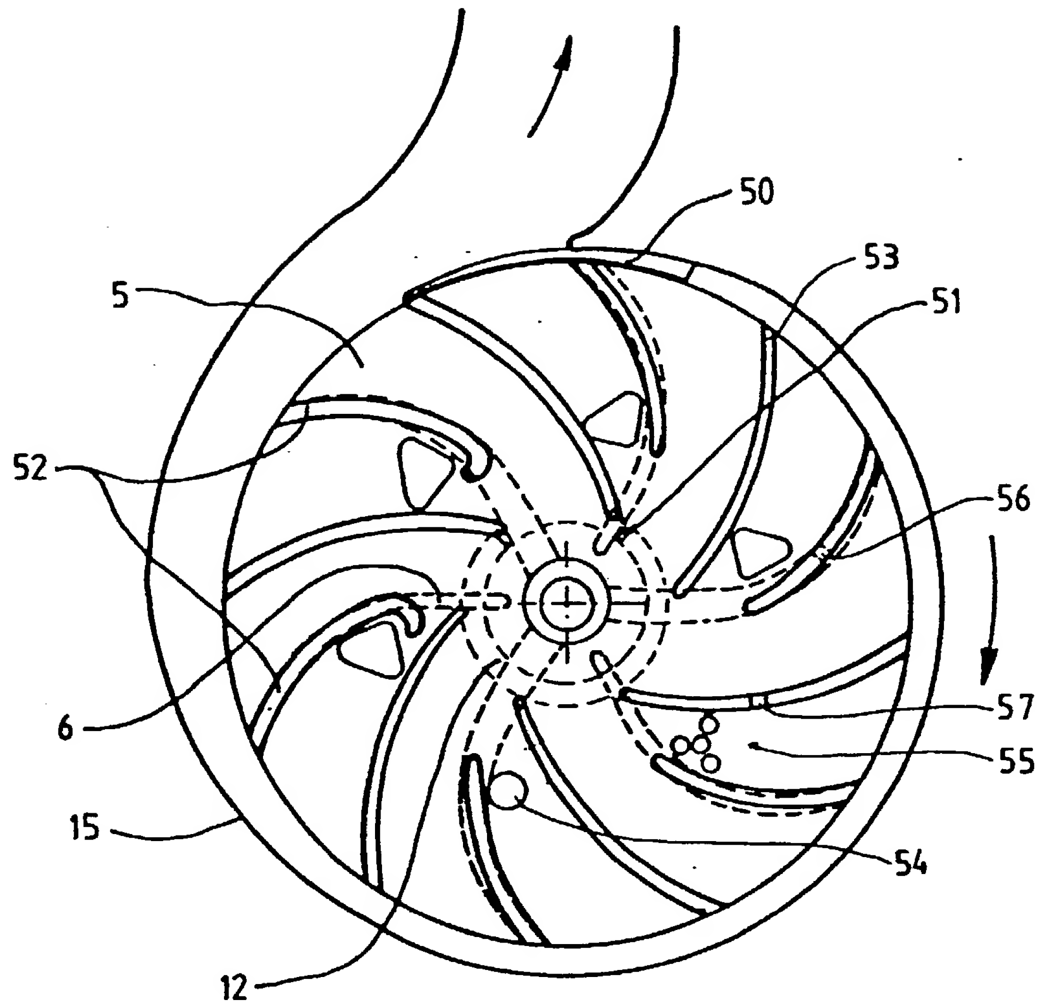

FIG. 6

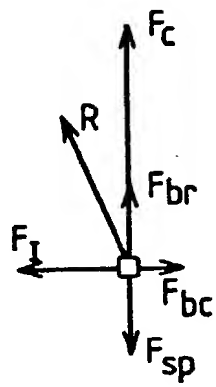

FIG. 7a

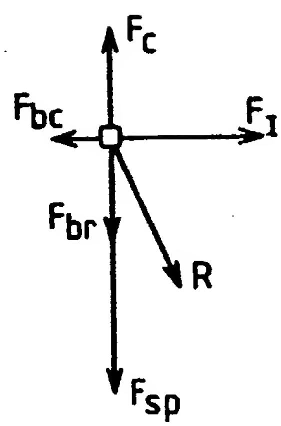

FIG. 7b